

EOS LAM-1

Mission Operations Concept

DRAFT

10/22/97

PREFACE

This paper documents the current operations concept for the EOS LAM-1 spacecraft. The primary motivation for this document is to facilitate a consistent understanding of LAM-1 operations concept by the entire LAM-1 team: FOT, EOS LAM-1 Project, spacecraft contractor, ESDIS Project, GLAS instrument team, and science team. It is expected that this paper, which presents a draft LAM-1 operations concept, will be subject to revisions based upon further coordination and inputs by the LAM-1 mission team. It is also expected that this paper will be a precursor to a LAM-1 Operations Concept Document, where these concepts will be developed in greater detail.

It was not the intent of this paper to reinvent the wheel. Much work has been done on the generic operations concept for EOS. In particular, the ECS Operations Concept Part 2, FOS and the EOS Mission Operations Concept Document both describe the generic operations concepts for EOS missions. This paper will focus on describing the LAM-1 mission-specific implementation of generic EOS operations concepts. This paper will also develop in further detail those concepts which depend upon specific spacecraft and ground system capabilities in order to provide a long lead time for implementation or operations concept revision.

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Reference Documents

- ECS Operations Concept for the ECS Project: Part 2, FOS, October 1995 (604-CD-004-001)
- 1995 EOS Reference Handbook
- EOS Ground System Architecture Description Document (GSFC ESDIS / Code 423)
- EOS Polar Ground Station Phase 2 Requirements Document, ESDIS Level 2 Requirements Volume 7 (Draft 1997)
- EOS Mission Operations Concept Document, September 1996 (GSFC ESDIS / Code 423)

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1.0 LAM-1 MISSION OVERVIEW

The Laser Altimetry Mission (LAM-1) is part of the Earth Observing System (EOS) multi-mission program to acquire the data necessary for the long-term study and understanding of Earth's global processes and systems. The LAM-1 spacecraft is a 3-axis stabilized, self-contained free-flyer, operating in a circular orbit at an altitude of approximately 600 km and an inclination of 94° with an orbital period of approximately 90 minutes. Nominal mission duration is 5 years (3 year design lifetime for spacecraft and instruments) and includes near-continuous nadir-pointing data collection.

LAM-1 is the first in a series of LAM spacecraft whose major science objective is the precise determination of ice sheet surface elevations. The Laser Altimetry missions will measure changes in surface heights of ice sheets and oceans to determine changes in the size of ice sheets. Investigators will use this information along with models of ice dynamics, and observations of temperatures and precipitation in polar regions to predict changes in ice volume and sea level. The LAM-1 mission will also provide valuable data on the structure and distribution of water vapor clouds and aerosols, supporting investigations of the Earth's radiation budget, greenhouse gases, and their affect on the climate (temperatures, winds, ocean currents).

The LAM missions are single-instrument missions utilizing the Geoscience Laser Altimeter System (GLAS) instrument mounted onboard the LAM spacecraft. The GLAS instrument supports both the primary ice sheet measurement requirements and supplies cloud and aerosol data as a secondary data product. The instrument is developed by the GSFC. The LAM-1 spacecraft supports the GLAS instrument by providing power, data services, thermal control, spacecraft pointing control, orbit maintenance propulsion, and space-to-ground communications.

The EOS Ground System (EGS) provides the LAM-1 mission with communications, flight operations, science data processing, data archival, and data distribution. Figure 1-1 provides a mission concept overview, including data flows for the LAM-1 mission.

1.1 Operations Overview

LAM-1 operations are highly autonomous. Science data are continuously collected in a nadir-pointing attitude maintained by the onboard flight software. Data generated by the instrument is stored on the SSR along with housekeeping data from the instrument and spacecraft for later downlink to a ground station. The EOS Polar Ground Stations will provide at least 4 ground station passes per day to support data downlink, spacecraft monitoring, and command uplinks.

The LAM-1 mission will be operated from the multi-mission EOS Operations Center (EOC). Mission operations at the EOC include integrated planning and scheduling of the LAM-1 spacecraft and instrument, generation of command loads for spacecraft and instrument control, and health and safety monitoring of the LAM-1 spacecraft and GLAS instrument. In addition, the EOC leads the coordination and scheduling of all EOSDIS elements, NASA institutional resources, and any other external participants for LAM-1 mission operations support, and schedules ground station support for communications contacts.

The GLAS Instrument Operations Team (GLAS IOT) supports EOC instrument planning, instrument command load generation, and instrument status monitoring from remote locations using EOSDIS Instrument Support Toolkits (ISTs). The autonomous nature and routine operations requirements of the LAM-1 mission and GLAS instrument minimize the need for high levels of real-time participation by the GLAS IOT.

Reference the [ECS Operations Concept Part 2, FOS](#), DID 604-CD-004-001, Section 3.4 Flight Ops Concept, for a more detailed description of the generic EOS flight operations concept. LAM-1 specific operations concepts and mission implementation details are developed further in subsequent sections of this paper.

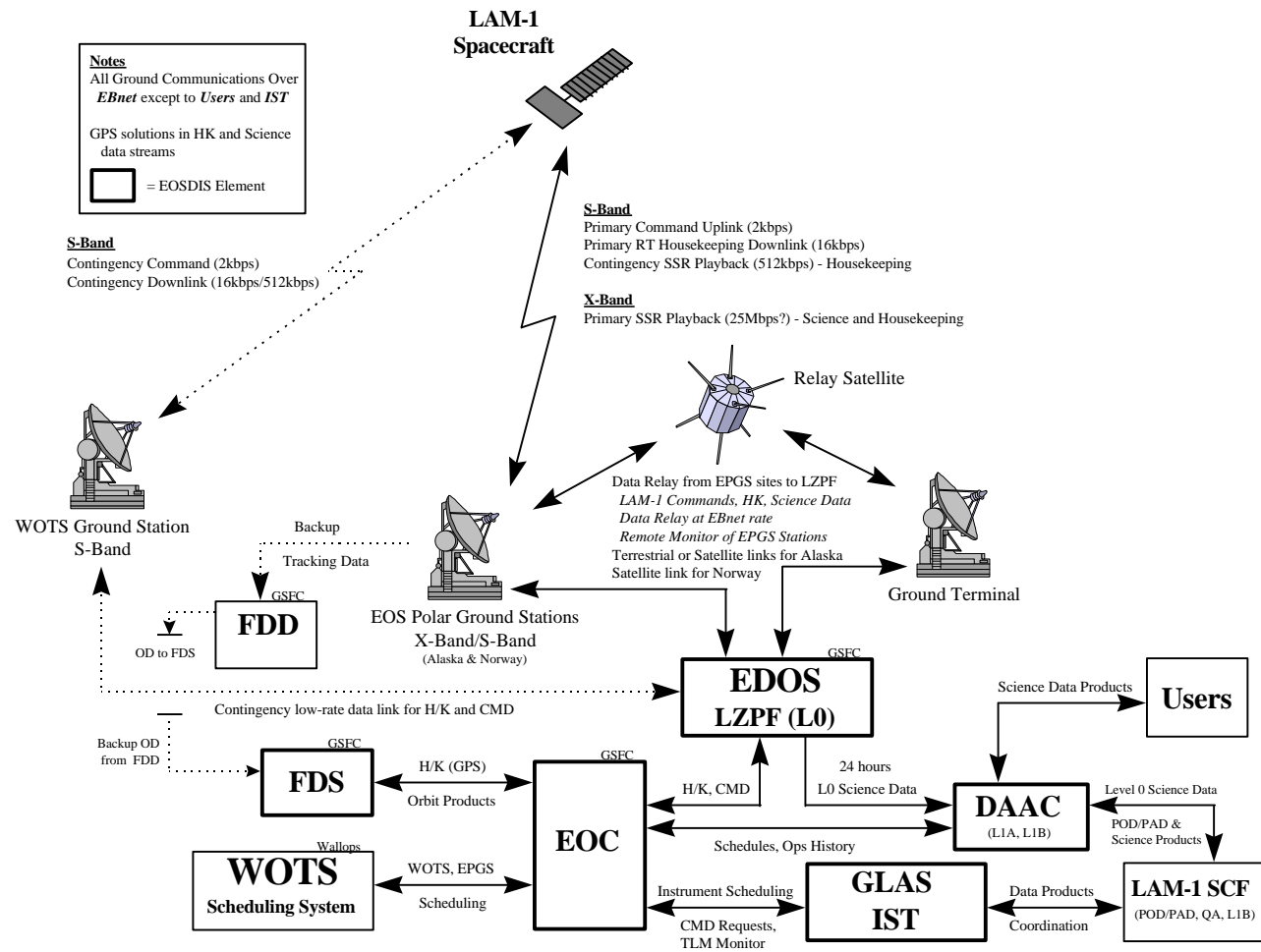


Figure 1-1 EOS LAM-1 Operations Concept Overview

2.0 SPACECRAFT OPERATIONS

2.1 *Multi-Mission Operations*

The EOS Ground Segment (EGS) supports multiple EOS missions in various stages of development or operations simultaneously. The EOS AM-1 and PM-1 missions will be in the middle of their operational lifetimes at LAM-1 launch, and before the termination of the LAM-1 mission, the CHEM-1, AM-2, and PM-2 missions will begin on-orbit operations.

All EOS missions are operated by the EOS Flight Operations Team (FOT) out of the EOS Operations Center (EOC) at GSFC. Operations for all missions are performed primarily during the day shift, with off-shift support limited to executing pre-planned spacecraft contacts and monitoring mission status.

EOC staffing will transition from a full AM-1 team to a shared team for common functions with flight-specific or series-specific (AM, PM, LAM, CHEM) experts dedicated to each mission or series of missions. This builds expertise in critical spacecraft-specific and instrument-specific operations while reducing staff through shared generic functions where possible. Staffing levels for each mission will start out high during initial on-orbit checkout phases, and will be adjusted appropriately as operations are better understood and automated software is brought online and validated.

Contention for time-critical EGS resources is avoided through a ground system design which can process multiple spacecraft streams in parallel, and through coordinated orbit constellation design which minimizes simultaneous support requirements among several spacecraft. Each EOSDIS element in the real-time or near-real-time critical path will contain multiple processing strings to allow simultaneous operations with multiple spacecraft. For example, EDOS and the EOC are each designed to support simultaneous multi-mission operations through separate functional strings for each spacecraft.

Multi-mission contention for EPGS downlink support is illustrated in Figure 1-2. The EPGS ground stations will provide RF support to all EOS missions as well as Landsat-7 and EO-1. Figure 1-2 is based on the current EOS constellation design and assumes all spacecraft are downlinking to a single antenna at a single site. The constellation design was chosen to minimize overlapping coverage requirements and space missions according to total data volumes, allowing adequate time for retransmission of science data from EPGS to EDOS at GSFC without incurring delays. LAM-1 is not in a sun-synchronous orbit, and contact times will therefore shift compared to the rest of the spacecraft supported by the EPGS sites.

The current plans for EPGS implementation call for 2 antennas at Norway and 1 at Alaska. The multiple antennas relieve any concern for conflicting coverage between LAM-1 and other missions, and provide good margins to support all current EOS mission communications requirements.

2.2 *Communications Overview*

The EOS Polar Ground Stations (EPGS) in Alaska and Norway will provide the normal communications link to all the EOS spacecraft, including LAM-1. The LAM-1 S-Band downlink provides real-time spacecraft and instrument housekeeping data, and the LAM-1 X-band system supports high-rate playbacks of stored housekeeping and science data. LAM-1 command uplink is via S-band. The Wallops Orbital Tracking Station (WOTS) provides contingency S-Band RF support for LAM and the other EOS missions.

Due to the highly inclined orbit of the LAM-1 spacecraft and the northern location of both EPGS ground stations, coverage times will be nearly contiguous between the two stations. (reference Table A for station viewing periods and TABLE B for data volumes and downlink times).

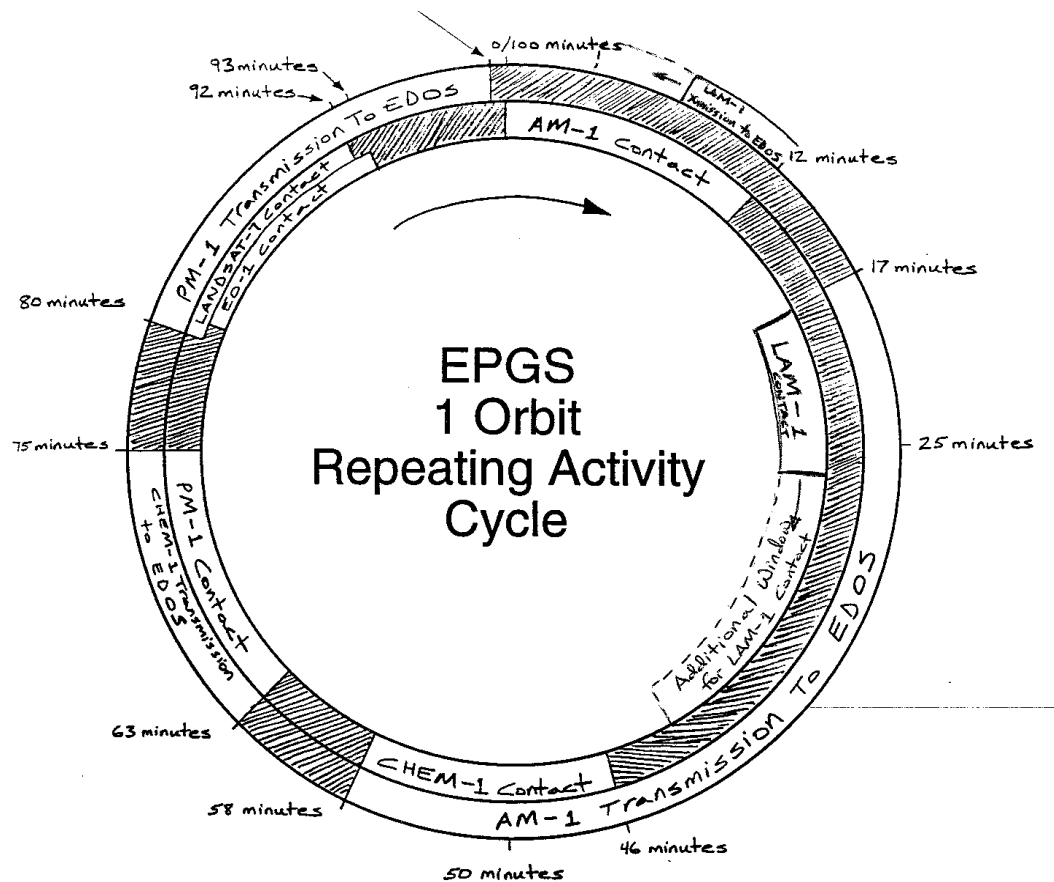


Figure 1-2 EPGS Repeating Orbit Activity Cycle

Notes

- All mission contact times (except LAM-1) are fixed relative to each other.
- LAM-1 contact time will shift due to its non-sun-synchronous orbit.
- Transmission times based upon mission data volumes and 45Mbps EBnet data rate.
- Diagram depicts contacts at a single ground station.
- Relative contact times based on latest EOS constellation design.

• **TABLE A: LAM-1 EPGS Viewing Periods**

	Norway	Alaska	Total ¹
Orbit 1	7:48	8:00	15:48
Orbit 2	9:12	10:18	19:30
Orbit 3	10:18	10:06	20:24
Orbit 4	10:36	6:24	16:50
Orbit 5	10:24	0	10:24
Orbit 6	9:54	0	9:54
Orbit 7	9:42	0	9:42
Orbit 8	9:54	0	9:54
Orbit 9	10:18	0	10:18
Orbit 10	10:36	7:30	17:56
Orbit 11	10:24	10:24	20:48
Orbit 12	9:24	10:06	19:30
Orbit 13	8:00	7:18	15:18
Orbit 14	6:42	0:42	7:24
Orbit 15	6:42	4:00	10:42
Total	139:42	74:36	214:18
Average	9:18	5:00 ²	14:18

Note 1: Total adds orbital coverage times for Alaska and Norway (\$minimum elevation).
Overlap will reduce useful coverage slightly.

Note 2: Alaska average is for all orbits (including orbits with no coverage).

TABLE B: Data Volumes & Downlink Time

LAM-1 Component	Data Rate (kbps)
GLAS	207.33 ¹
GPS	TBD
S/C H/K	8
Total Rate (kbps)	215.33
Including 15% Overhead	247.63
Gbits Per Day	21.40
25Mbps X-BD Dnlnk Time	14:16 ²

Note 1: GLAS data rate includes 2/3 data compression. Actual GLAS data rate is 311 kbps.

This rate may be revised downwards based on ongoing LAM Project negotiations.

Note 2: 25Mbps LAM-1 X-band downlink rate is preliminary.

At least four (4) ground station contacts per day will be scheduled from the available viewing periods to support LAM-1 operations. Additional contacts will be scheduled as required to support contingency operations or periodic normal operations which require additional coverage. Reference Figure 1-3 for a typical LAM-1 pass plan. The onboard solid state recorder (SSR) will have a capacity of at least 15 Gbits. This gives the SSR 18 hours of capacity at the current instrument and spacecraft data rates (reference Table B), providing the flexibility to reduce coverage without losing science data.

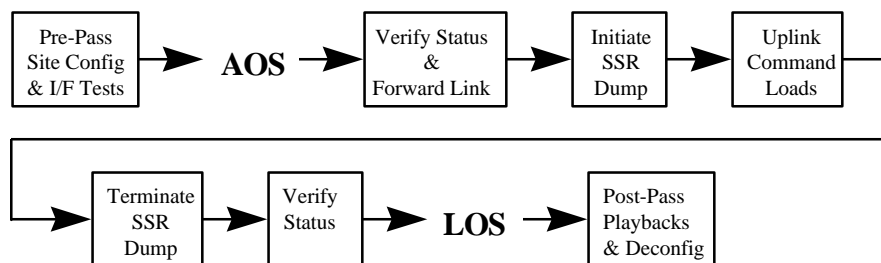


Figure 1-3 Nominal EOS LAM-1 Pass Plan

2.3 *Health & Safety Monitoring*

The EOC will be responsible for LAM-1 spacecraft and instrument health & safety monitoring in real-time, and will respond to time-critical anomalies using pre-approved procedures. During the off-shift, a small shared team monitors the status of all EOS spacecraft, and pages specific spacecraft experts if a critical anomaly occurs.

The EOC has two nominal sources for LAM-1 health & safety data:

- Real-time housekeeping data 4 times per day (~10 minutes each) via EPGS S-band link
- SSR recorded housekeeping data dumped each contact via EPGS X-band link

Real-Time Housekeeping Data

The EPGS ground station forwards the entire S-Band downlink to EDOS via a commercial satellite or terrestrial link in real-time (WOTS sends only the 16kbps real-time portion to EDOS in real-time). EDOS strips out and forwards the real-time data to the EOC for real-time command control and status monitoring. Real-time data received at the EOC is automatically processed by limit-checking and rules-based software to verify nominal spacecraft and instrument status. Time-critical anomalies will cause an alert, and the LAM-1 Spacecraft Evaluator will respond using approved procedures. Real-time data also provides the EOC with the Command Link Control Words (CLCWs) required to support CCSDS COP-1 command processing protocols.

Playback Housekeeping Data

Spacecraft housekeeping and science data will continue to be recorded onboard during any playbacks. Playback housekeeping data is nominally dumped from the SSR with the science data on the 25Mbps X-band downlink. A full day's worth of recorded housekeeping data (at 16kbps continuous rate) will take approximately 60 seconds to downlink at 25Mbps. Since there are 4 nominal contacts per day, about 6 hours apart, housekeeping downlink time requirements per contact is limited to about 15 seconds. The SSR playback is performed in priority order, with housekeeping data dumped first to support health & safety monitoring. The 25Mbps X-band playback is forwarded to EDOS post-pass, with the housekeeping data forwarded first (determined by the order of the downlink). Housekeeping data is identified by virtual channel ID at EDOS, stripped out and sent to the EOC in near-real-time.

In a contingency mode, recorded housekeeping data can be dumped from the SSR via a high-rate S-Band downlink (512kbps). This mode will be used when the X-band is not available or when performing contacts with the WOTS contingency ground station (which is not required to support X-band dumps from EOS spacecraft). 16kbps real-time data will be downlinked in the same link (on a separate virtual channel), so 496kbps of bandwidth is available for the housekeeping playback. EPGS forwards the full 512kbps S-Band downlink to EDOS in real-time.

The X-band dump recorded at the ground station (or S-Band dump from WOTS) is forwarded to EDOS over a high rate commercial satellite or terrestrial link immediately after the real-time contact is terminated. The nominal 5 minute 25Mbps downlink (performed during each of the 4 nominal contacts spread evenly throughout the day) will take 4 minutes to play back to EDOS at an accelerated rate of 31Mbps. The dumps include both instrument science data and housekeeping data from the previous 6 hours.

Upon receipt from EDOS, playback housekeeping data is automatically run through automated limit-checking software, rule-based software monitoring routines, statistical checks, and other software tools at the EOC to verify nominal operation of the spacecraft and instruments. Indicated violations cause alerts and are investigated by the LAM-1 Spacecraft Evaluator, and appropriate actions are recommended to the LAM-1 Operations Controller.

Housekeeping Data via IST

Instrument housekeeping data will be available to the instrument teams through the ISTs. The instrument teams will perform long-term trending and instrument health analysis at their home facilities. Instrument teams may provide inputs and make inquiries to the LAM-1 Spacecraft Evaluator concerning instrument health & safety at any time. Instrument teams are the source for all instrument limits, rules, and response procedures used by the LAM-1 Spacecraft Evaluator for instrument monitoring at the EOC.

Memory Dumps

When a processor memory dump is required, it is commanded in real-time and downlinked via the S-band link to an EPGS or WOTS ground station. Details of memory dump operations are TBD based on spacecraft design. Memory dump data is identified by VCID or APID at EDOS, and forwarded to the EOC for analysis. Stellar Reference System dumps will also require a high-rate downlink path (S-Band or X-Band TBD).

Sustaining Engineering

Sustaining engineering concepts for the LAM-1 mission will follow the generic EOS mission concept. Spacecraft trending, analysis, and calibrations will be performed by the EOC FOT, with support from FDD and the spacecraft contractor as required. SDVF will provide LAM-1 spacecraft flight software maintenance. Instrument sustaining engineering, including all calibrations and flight software updates, will be provided for by the GLAS IOT, who will have access to all instrument and spacecraft data via IST interface to the EOC. The EOC FOT may support GLAS IOT instrument sustaining engineering functions by performing routine trending and analysis as defined by the GLAS IOT.

Instrument Health & Safety Monitoring

The EOC has primary responsibility to perform time-critical health & safety monitoring of the LAM-1 spacecraft and instrument. The EOC will monitor instrument status using real-time and back-orbit housekeeping data downlinked to the EPGS ground stations. Data is transferred to the EOC via EDOS for automated limit and rules processing. Alerts and pages will notify the Spacecraft Evaluator of anomalies discovered by the software. Pre-mission, the GLAS IOT will develop limit sets, rules, and standard anomaly response procedures for use by the EOC for maintaining the health & safety of each instrument.

The GLAS IOT has near-real-time access to all instrument (and spacecraft) housekeeping and engineering data through remote login to the EOC via their ISTs. This data will be used primarily to support instrument sustaining engineering functions in an offline mode. However, in contingency situations or during checkout activities, instrument teams may use the data to participate in health & safety monitoring activities.

2.4 Integrated Mission Planning

The LAM-1 mission will follow the generic mission planning and scheduling concepts developed for EOS missions. All mission planning and scheduling activities for LAM-1 will be performed at the EOC during the day shift, 7 days per week.

Long-Term Mission Planning

The Instrument Working Group (IWG) and project scientist will define instrument goals and objectives pre-mission, as well as a Baseline Activity Profile (BAP) for the LAM-1 instrument (GLAS). The EOC will maintain the instrument BAP, and develop and maintain a spacecraft subsystem BAP for routine spacecraft operations. The integrated BAP will define operations and data collection requirements to the extent necessary for EOC schedulers to determine orbital recorder data volumes and to produce daily detailed activity schedules for the instrument and spacecraft.

Initial Weekly Scheduling

Weekly scheduling is performed by the EOC LAM-1 Spacecraft Scheduler. Deviations from instrument BAPs are submitted by the EOC instrument scheduler to the LAM-1 spacecraft scheduler via the IST interface. Instrument schedulers coordinate with the GLAS IOT to generate deviation inputs. Spacecraft BAP deviations are submitted by the EOC LAM-1 spacecraft engineering personnel. Using the instrument BAP, submitted instrument deviations, and spacecraft BAP with required spacecraft deviations, the LAM-1 spacecraft scheduler generates and validates the required resource profile for the target week. Based on these generated resource profiles, predicted groundstation coverage times, and spacecraft resource availability, the EOC Spacecraft Scheduler validates that the resource profile does not exceed capabilities at any time during the week. Negative margin on resources is resolved as part of the initial scheduling process through coordination with instrument schedulers, GLAS IOT, spacecraft schedulers, and ground station personnel. All initial scheduling products will be available for review by the GLAS IOT and the full science team via their ISTs.

As part of initial scheduling, the EOC will coordinate with Wallops for scheduling of the EPGS ground stations. Normally, four LAM-1 contacts per day will be supported by the EPGS ground stations (Alaska, Norway). Data routing at the EDOS will determine which site commands are routed to and which site's acquired real-time data will be sent to the EOC (TBD). Additional ground station contacts will be scheduled as required to support off-nominal operations.

The scheduling of WOTS for LAM-1 contingency pass support will also occur as part of initial scheduling. The EOC will use the same Wallops interface for the scheduling of WOTS for LAM-1 support.

Final Scheduling

Final scheduling consists of generating an integrated spacecraft/instrument detailed activity schedule. Schedules are generated by the EOC spacecraft scheduler based upon BAPs, deviations for the spacecraft and instrument, and ground station contact times. Detailed activity schedules are distributed for review to the EOC LAM-1 engineering personnel, GLAS IOT, and science team via their IST terminals. The detailed activity schedule is then validated using resource constraint algorithms, and any final conflicts resolved. Integrated command loads are built automatically by the Command Management System (CMS) based upon the detailed activity schedule and pass plans (including real-time commands) are generated at the EOC and validated using FOS tools. EPGS ground stations are notified of primary/secondary support status and predicted playback times as part of the final scheduling process. Reference section 2.2 (Command Operations) for further commanding details. Late changes and TOOs are implemented through the uplink of new command loads to replace those already onboard. These new loads are validated on the ground before uplink to ensure that resource constraints will not be violated by the new changes.

Instrument Mission Planning & Command Inputs

For the LAM-1 mission, all real-time commands and command loads for both the spacecraft and instruments are built, validated, and transmitted from the EOC based on pre-mission developed instrument Baseline Activity Profiles (BAPs) and instrument command and telemetry databases. The GLAS IOT makes inputs for revisions to their instrument BAP or databases as required during the course of the LAM-1 mission. The databases and BAPs for all instruments (and spacecraft) are maintained by the FOT at the GSFC EOC.

The GLAS IOT (at the GLAS IST) collects inputs from the entire LAM-1 science team via distributed ISTs, and provides coordinated inputs to the EOC for mission planning and operations. Inputs may include instrument mode changes, calibrations, or individual command requests as required. The entire LAM-1 science team has access to the latest planning products and schedules via the LAM-1 ISTs. The lead GLAS IST may contact the LAM-1 Instrument Scheduler at the EOC at any time to request information or provide an input.

During instrument checkout or instrument anomaly resolution, the instrument teams may be remotely connected via their ISTs to review data and make real-time command requests to the EOC through the GLAS IST.

2.4 Command Operations

All spacecraft and instrument command loads are sent from the EOC by the LAM-1 Command Activity Controller during the day shift. Stored command loads for the instrument and spacecraft are uplinked to allow adequate time for verification and re-uplink, if required. While specific commanding requirements have not yet been determined, it is expected that a typical 9 minute EPGS contact will provide adequate time for the daily command load uplink requirements at 2kbps. With proper design, the LAM-1 stored command loads will cover routine onboard commanding requirements for up to 1 week at a time.

Command loads and real-time commands are generated at the EOC (see Section 2.3, above) using the command management system and spacecraft and instrument command databases maintained at the EOC. Instrument command loads are generated at the EOC based upon GLAS IOT BAPs and GLAS IOT-submitted deviations. Similarly, spacecraft subsystem command loads are generated at the EOC based upon the spacecraft BAP and subsystem engineer-submitted deviations. Flight software patches, if required, will be generated and validated by the GLAS IOT (for the instruments) or by the GSFC Software Development and Validation Facility (SDVF) (for the spacecraft). The FDD system will generate state vector updates for uplink and command loads for periodic orbit maintenance maneuvers. All of the various command inputs are integrated into pass plans by the LAM-1 Command Activity Controller during the final scheduling phase.

Commanding is performed during real-time contacts with the spacecraft through the EPGS ground stations. Commanding is executed by the LAM-1 Command Activity Controller at the EOC with pre-built pass plans, and real-time telemetry is used to verify a good link before uplink begins. Commands sent from the EOC are transmitted in real-time over the EBnet to EDOS, and throughput from EDOS to the appropriate ground station for uplink at 2kbps. The CCSDS Command Operations Procedure 1 (COP-1) is executed over the spacecraft-to-EOC real-time link, and ensures that commands get onboard without errors and in the proper order. Successful commanding is also confirmed by CRC checks, stored command table memory dumps, and housekeeping telemetry.

EOC pass plans (also known as ground scripts) which control command uplinks will run automatically, and will be monitored by the LAM-1 CAC. Failure of automatic pass plan execution will be handled by manual execution. The use of automated pass plans for the LAM-1 mission will rely on successful development and verification of this capability during the AM-1 and PM-1 missions, and will be implemented following successful verification during the LAM-1 activation and checkout period. Note that pass plans include pre-pass network and ground station configuration verifications, as well as real-time commanding and command load uplinks.

In addition to the command loads (stored commands, ephemeris updates, tables, flight software patches) nominally uplinked once per day or less, real-time commanding will be required on each scheduled pass in order to dump the solid state recorder (SSR), perform memory load and dump control and spacecraft system reconfigurations (as required). All science and housekeeping data is recorded on the SSR. EOC pass plans control all real-time commanding. See Section 2.3 and 3.3 for SSR dump details.

2.6 Tracking & Flight Dynamics Support

All routine orbit determination, propagation, and planning aid generation activities will be performed on FDD-provided systems at the EOC by EOC planning and scheduling personnel. FDD support will provide maneuver planning, calibration support, performance analysis, and consulting to LAM-1 and other EOS missions as required. All flight dynamics support is performed during the day shift.

Operational Orbit Determination

Medium precision orbit determination (to 50 meter accuracy) is performed onboard by the GPS system. Orbit solutions calculated onboard by the GPS system are stored on the SSR and downlinked as part of the housekeeping playback. Orbit solution data is routed from EDOS to the EOC FDD systems in near-real-

time along with the rest of the playback housekeeping data. FDD systems may be used to reprocess the downlinked GPS data to achieve the solution accuracy required to support maneuver planning and orbit maintenance.

Orbit Propagation for Mission Planning

The EOC FDD system will propagate LAM-1 orbit solutions for mission planning and scheduling purposes, and perform all required constraint verification and orbital event generation.

Onboard State Vector Maintenance

The onboard state vector used in ACS processing can be updated autonomously with the onboard GPS solution or updated via ground uplink of the same solution (TBD).

Spacecraft Clock Correlation

The method used for onboard clock error determination and update is TBD. GPS and EPGS options are available, with onboard GPS updates preferable (flight software implementation).

Orbit & Attitude Maintenance

Periodic orbit maneuvers will be required to maintain the LAM-1 spacecraft orbit within requirements. FDD will provide maneuver planning support to the EOC using FDD-provided systems. Pre-mission orbit design and on-orbit maintenance coordination between LAM-1 and other EOS missions will help to reduce ground station coverage conflicts.

The nominal operational mission attitude is nadir-pointing. However, attitude adjustments may be required periodically to achieve desired ground track repeats for the sensor footprint, or to acquire special targets off-nadir. The EOC shall have attitude tools necessary to compute these maneuvers based on housekeeping attitude data. Calibration of the onboard attitude control system is TBD.

Precision Orbit/Attitude Determination

LAM-1 spacecraft operations do not require precision orbit or attitude determination at the EOC. Reference section 3.4 for POD and PAD processing at the LAM-1 SCF to support science data product generation.

Backup Orbit Determination

Tracking data from EPGS ground stations will be used by FDD to perform orbit determination in contingency situations when the onboard GPS system has failed. Orbit solutions will be passed from FDD to the flight dynamics system in the EOC for use in the generation of orbit products. The number, type, and duration of tracking passes, as well as the precision of solutions is TBD. However, it is known that this backup method of tracking will not meet post-processing science requirements for precision orbit determination. Ground tracking will be used to meet operational requirements until the GPS system is recovered.

2.7 Instrument-Specific Operations Information - TBD

This section will include specific information concerning the unique aspects of operations of the GLAS instrument. Included will be overviews of operations, commanding requirements, IST and ICC plans, real-time and offline monitoring and analysis responsibilities, scheduling and planning interfaces, and DAAC processing, archival, and distribution details for GLAS-specific data.

2.8 Special & Contingency Operations

(TO BE DEVELOPED FURTHER BY THE LAM-1 INSTRUMENT AND SCIENCE TEAMS)

LAM-specific details for the special operations listed below have not yet been developed, but are expected to follow closely with the concepts used for the EOS AM-1 mission. Both the spacecraft contractor and instrument teams will support launch, early orbit, activation, and checkout periods, with various teams leading their portion of the operations during these phases, and handing over to the FOT for nominal operations. Prelaunch integration and testing will include interface testing, string and end-to-end testing, acceptance testing, operations simulations, and final readiness testing.

Prelaunch Integration & Test Operations Concepts

Launch & Early Orbit (Activation & Checkout Period)

The LAM-1 spacecraft will be launched into a verification orbit. An orbit maneuver will be performed to transfer the spacecraft to its operational orbit. (Details TBD)

L&EO Communications

The EPGS ground stations will be scheduled to support the LALT-1 mission with communications contacts every orbit during the critical first days following launch of the spacecraft. Activation and checkout requirements (TBD) will determine the number of contacts required following initial on-orbit stabilization of the satellite. As activation & checkout tasks are completed and the mission enters its normal science data collection mode, the number of passes will be reduced to the nominal 4 per day.

Anomaly Resolution

3.0 SCIENCE OPERATIONS

(TO BE DEVELOPED FURTHER BY THE LAM-1 INSTRUMENT AND SCIENCE TEAMS)

3.1 Science Data Acquisition

Science data from the LAM-1 GLAS instrument is stored onboard the LAM-1 spacecraft in the SSR. The SSR is partitioned into areas for instrument and spacecraft housekeeping, and CCSDS virtual channel downlinks simplify prioritized ground processing and data routing at EDOS. Four times per day, the SSR is dumped via a 25Mbps X-band downlink to one of the EPGS ground stations in Alaska or Norway. The data recorded on the SSR is dumped in priority order. The SSR will have a capacity of 15Gbits, providing 18 hours of recording capacity based on expected LAM-1 instrument data rates (reference Table B in Section 1.2). Six hour's worth of science data will take approximately 4 minutes to downlink via the X-band link, and an average of almost 14 minutes is available each orbit through combined coverage from the EPGS ground stations. A full recorder will take 10 minutes to dump via the X-band link.

Data acquired at the ground stations is recorded and forwarded to EDOS at a rate of at least 31Mbps. The first data down (highest priority) is forwarded first. The 4 daily playbacks to EDOS should be complete within 9 minutes of the end of the ground station contacts. EDOS performs level zero processing of the science data, and forwards the data to the appropriate DAAC for further processing, archival, and distribution.

3.2 Science Data Processing

EDOS performs level zero science data processing on all instrument and spacecraft data. Processing is accomplished in priority order, based on pre-coordinated direction from the EOC. Generally, housekeeping data from the spacecraft and instrument is processed first, followed by instrument science data. Level zero science data from the GLAS instrument is then forwarded over the EBnet to the appropriate DAAC for further processing and the generation of science data products and metadata. Spacecraft and instrument back-orbit housekeeping data are forwarded to the EOC for health & safety analysis.

The DAAC forwards LAM-1 level 0 science data to the LAM-1 SCF for ancillary science processing including precision orbit determination, precision attitude determination. SCF ancillary science data products are returned to the DAAC, where level 1 through level 4 science products are generated. Science data archive and distribution is also performed by the DAACs. Reference Figures 3-1 and 3-2 for an overview of science products and science product generation flow, respectively.

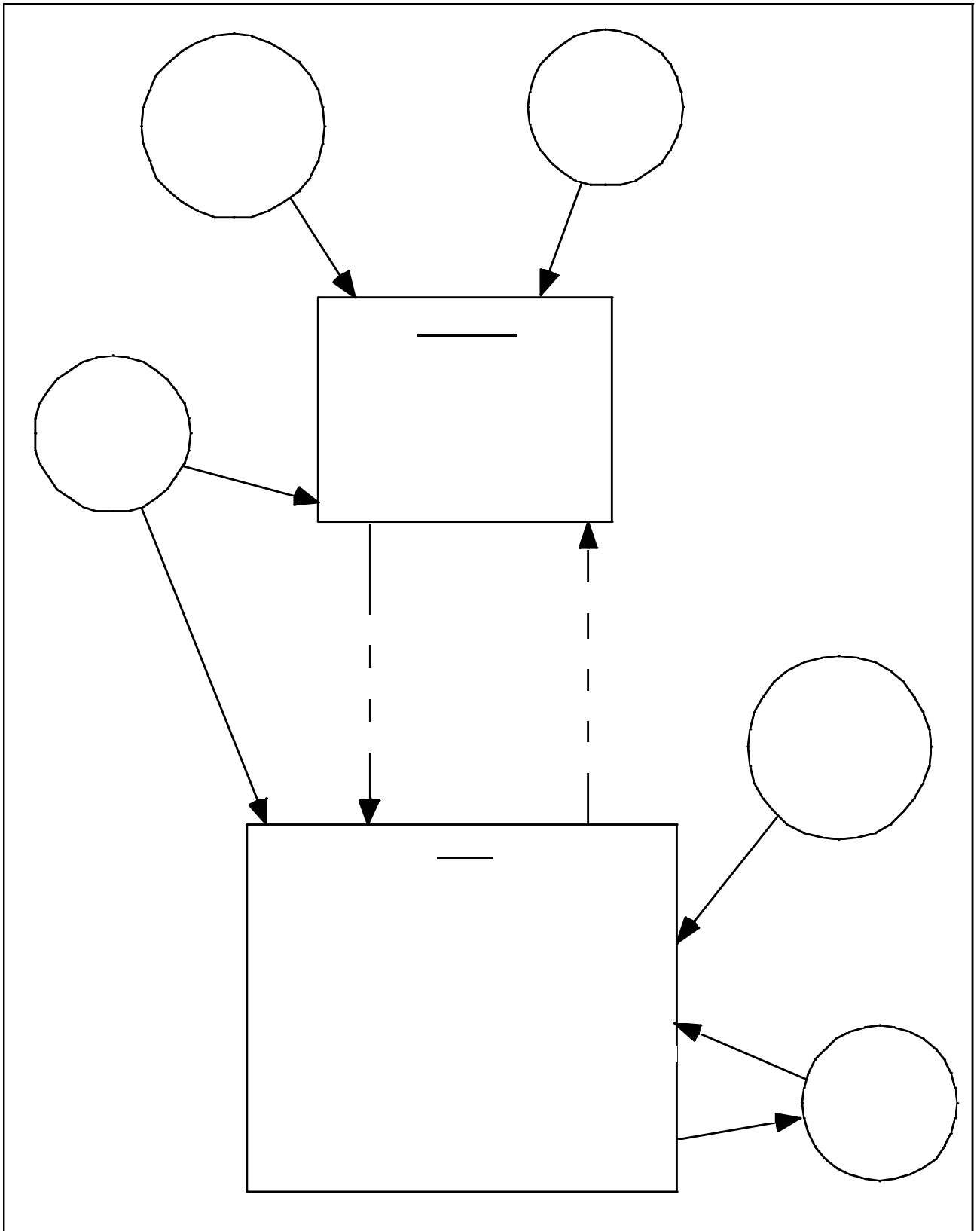


Figure 3-1 Science Product Overview

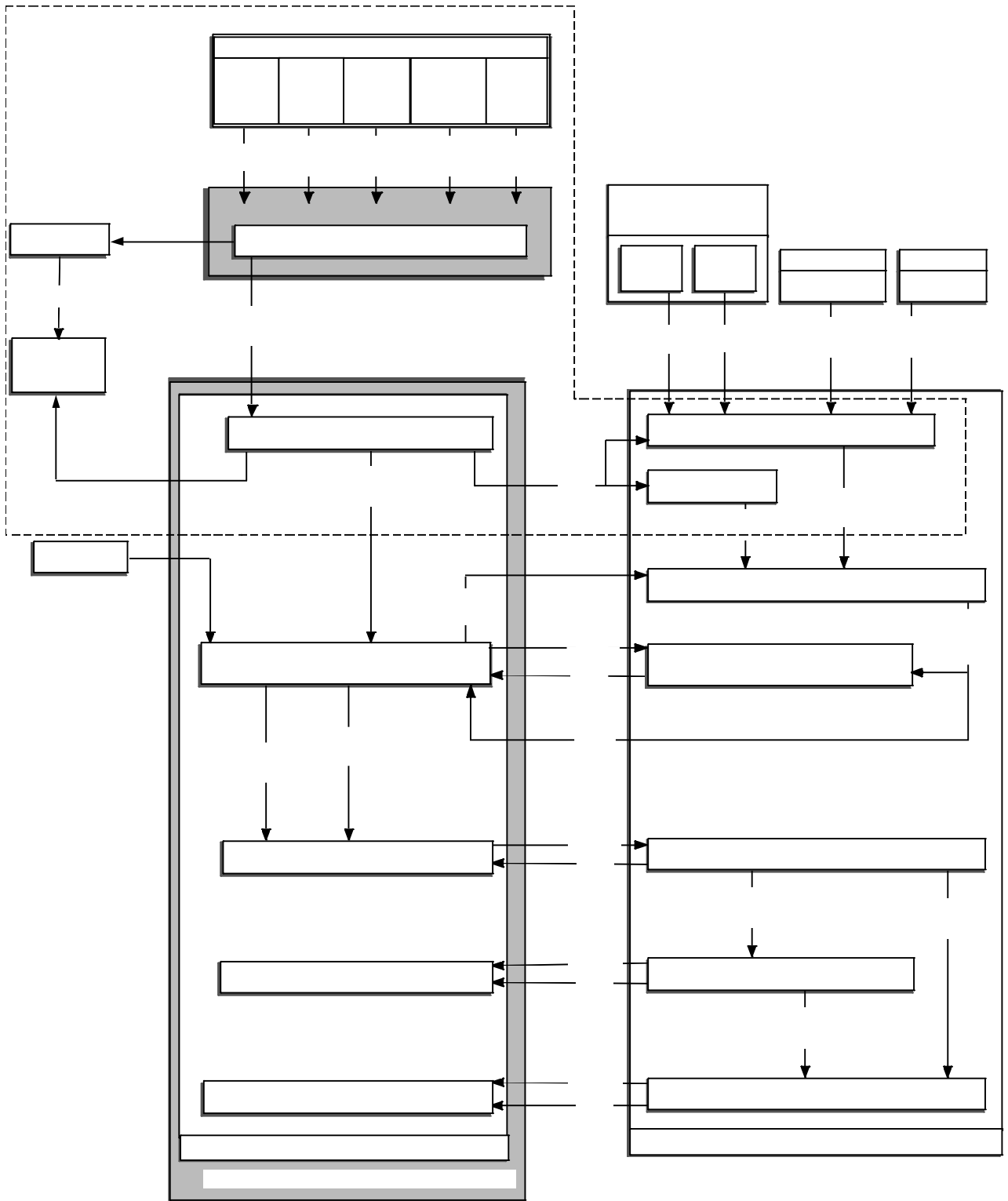


Figure 3-2 Science Product Generation Flow

ACRONYM LIST

ACS	Attitude Control System
AI	Artificial Intelligence
AIRS	Atmospheric Infrared Sounder
AM	EOS AM Mission
AMSR	Advanced Microwave Scanning Radiometer
AMSU	Advanced Microwave Sounding Unit
ASAP	As Soon As Possible
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BAP	Baseline Activity Profile
BD	Band
CAC	Command Activity Controller
CCSDS	Consultative Committee for Space Data Standards
CERES	Clouds & Earth's Radiant Energy System
CHEM	EOS Chemistry Mission
CMD	Command
CMS	Command Management System
CRC	Cyclic Redundancy Check
DAAC	Distributed Active Archive Center
EBNET	EOSDIS Backbone Network
EDOS	EOS Data and Operations System
EGS	EOS Ground System
EOC	EOS Operations Center
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
EPGN	EOS Polar Ground Network
FDD	Flight Dynamics Division
FIDR	Failure Detection, Isolation, Recovery
FOS	Flight Operations System
FOT	Flight Operations Team
FS	Slight Software
FWD	Forward
Gbit	Gigabit
H/K	Housekeeping
HSB	Humidity Sounder Brazil
ID	Identifier or Identification
IOT	Instrument Operations Team
IST	Instrument Support Toolkit
IWG	Instrument Working Group
KBPS	Kilobits Per Second
KM	Kilometer
LALT	EOS Laser Altimeter Mission
LEO	Low Earth Orbit
MA	Multiple Access
MBPS	Megabits Per Second
MGA	Medium Gain Antenna
MIN	Minutes
MODIS	Moderate Resolution Imaging Spectrometer
NCC	Network Control Center
NOAA	National Oceanic & Atmospheric Administration
PM	EOS PM Mission
PN	Pseudo-Random Noise
RF	Radio Frequency
RTCS	Relative Time Command Sequence
RTN	Return
SCF	Science Computing Facility
SDVF	Software Development & Verification Facility
SSA	S-band Single Access
SSR	Solid State Recorder
TBD	To Be Determined
TBS	To Be Supplied
TDRS	Tracking & Data Relay Satellite
TDRSS	Tracking & Data Relay Satellite System
TLM	Telemetry
TMON	Telemetry Monitor
TOO	Targets Of Opportunity
WOTS	Wallops Orbital Tracking Station